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Morphological and Cytological Variation in *Asarum fauriei* (Aristolochiaceae) in Central and Northern Honshu, Japan

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Morphological and cytological variation among populations of *Asarum fauriei* (Aristolochiaceae) in central and northern Honshu of Japan was examined. Triploid ($2n$=36) and diploid ($2n$=24) plants were found widely throughout the geographical range of the species. The chromosome numbers are mostly consistent within a study site, but rarely diploid and triploid plants grew side by side in the same locality, and two different triploid plants distinguishable from each other in leaf and floral aspects occurred in the same locality. The two different triploid plants appear to be of different origin and may have no direct relationships on the basis of morphological differences. Morphologically, all of the floral and leaf characters varied continuously, and no discrete gaps were found among populations. The populations, however, were clustered into three major groups when the data obtained from morphological characters were subjected to principal component analysis. Taxonomically, two of the three groups correspond to two infraspecific taxa, var. *fauriei* and var. *nakaianum*, and the other, which is mostly triploid and morphologically characterized by larger ovate leaves and longer calyx lobes relative to calyx tube, may be regarded as a new infraspecific taxon.

Key words: Aristolochiaceae, *Asarum fauriei*, *Asarum nakaianum*, diploids, Japanese Alps, morphological variation, principal component analysis, triploids

Asarum is a diverse genus of perennial herbs distributed in eastern Asia, Europe and North America. In the broad sense, more than 40 species have been attributed to the Japanese Archipelago (Ohwi 1975, Satake & Momiyama 1982, Sugawara 1991), and most of them usually grow in evergreen broad-leaved forests in lowlands in the warm temperate zone. *Asarum fauriei* Franch., however, grows in the higher mountains of the Japanese Alps and adjacent regions in the Chubu District of central Honshu and extends to lowlands in the Tohoku District of northern Honshu, Japan (Maekawa 1959, Kitamura & Murata 1961, Ohwi 1975, 1984). *Asarum fauriei* has generally been regarded as being adapted to the deciduous forests dominated by *Fagus crenata* in the Chubu and Tohoku Districts (Maekawa 1959), and is treated as comprising three infraspecific taxa, var. *fauriei*, var. *nakaianum* (F. Maek.) Ohwi and var. *serpens* F. Maek. (Ohwi 1975, 1984), although var. *nakaianum* was first described as a distinct species (Maekawa 1932). Among the three infraspecific taxa, var. *serpens* is a cultivar of gardens, and the other two occur naturally (Maekawa 1959, Ohwi 1975, 1984, Satake & Momiyama 1982). My concern was only with the wild plants occurring naturally.

Plants of var. *fauriei* and var. *nakaianum* usually occur in similar habitats and are similar in

TABLE 1. Collection sites, altitudes, sample sizes for observation of karyological and morphological features, somatic chromosome numbers counted in the present study, and voucher specimens. Abbreviations used in accessions: CHR, somatic chromosome number; SCH, sample size for observation of chromosomes; SFM, sample size for analysis of floral morphology; SLM, sample size for analysis of leaf morphology. Abbreviations used in voucher designation: TS, T. Sugawara; YH, Y. Horii; NF, N. Fujimaki; MS, M. Shinozaki.

Pop. no.	Locality	Altitude(m)	CHR(SCH)	SFM	SLM	Voucher specimen
NORTHERN HONSHU						
1.	Akita Pref.: Oodate City, Shirasawa	100	24 (1)	4	7	*TS940401*
2.	Akita Pref.: Senboku-gun, Kyowa-machi, Utsuno	100	24 (1)	12	11	*YH970425*
3.	Akita Pref.: Senboku-gun, Senboku-cho, Hotta	30	24 (3)	10	13	*YH950501*
4.	Akita Pref.: Senboku-gun, Tazawako-machi, Tagonoki	280	24 (3)	10	10	*YH960426*
5.	Yamagata Pref.: Akumi-gun, Yuza-machi, Iwano	150	24 (2)	4	7	*TS980401*
6.	Niigata Pref.: Iwafune-gun, Asahi-mura, Nakahara	20	24 (2)	12	11	*TS970409, TS980331*
7.	Niigata Pref.: Kita-uonuma-gun, Irihirose-mura, Hidarisawa Valley	730	36 (4)	6	15	*NF980522*
C1.	Aomori Pref.: Mutsu City, Akagawanuma	40	24 (1)			*TS900502*
C2.	Aomori Pref.: Higashi-tsugaru-gun, Kanita-machi, Kanita	50	24 (1)			*TS900501*
C3.	Aomori Pref.: Kamikita-gun, Kamikita-machi, Tokumanzai	80	24 (1)			*TS900503*
CENTRAL HONSHU						
8.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Misora I	730	24 (3)	16	17	*TS970418*
9.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Misora II	780	24 (3)	11	25	*TS980429, TS990405*
10.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Hirakawa	880	24 (2)	13	21	*TS940424, TS990404*
11.	Niigata Pref.: Itoigawa City, Shiroike II	1140	36 (8)	12	16	*TS990627*
12.	Niigata Pref.: Itoigawa City, Shiroike I	1100	36 (4)	11	12	*TS980510*
13.	Nagano Pref.: Oomachi City, Kurosawa	1140	36 (3)	7	17	*TS940423, TS990430*
14.	Nagano Pref.: Minami-azumi-gun, Azumi-mura, Nakanoyu	1450	36 (6)	10	21	*TS980520, TS990512*
15.	Nagano Pref.: Minami-azumi-gun, Nagawa-mura, Sakai Pass	1460	36 (3)	12	21	*TS980515*
16.	Gifu Pref.: Yoshiki-gun, Kamitakara-mura, Abo-daira	1600	36 (4)	7	11	*TS950524, TS980521*
17.	Toyama Pref.: Kami-niikawa-gun, Ooyama-machi, Hietsu Pass	1500	24 (3)	8	15	*TS980801, TS990526*
18.	Gifu Pref.: Yoshiki-gun, Kamioka-cho, Morimokitanomata	1480	24 (6)	8	10	*NF990515*
19.	Toyama Pref.: Kami-niikawa-gun, Ooyama-machi, Mt. Ooshina	1300	24(5)	15	25	*TS980704, TS990610*
20.	Toyama Pref.: Naka-niikawa-gun, Tateyama-machi, Bijodaira	980	24 (3)	8	15	*TS990611*
21.	Toyama Pref.: Naka-niikawa-gun, Tateyama-machi, Midagahara	1900	24 (3)	6	14	*TS990710*
22.	Toyama Pref.: Kami-niikawa-gun, Ooyama-machi, Ootawa Pass	1220	36 (3)	12	10	*TS990524A*
23.	Toyama Pref.: Kami-niikawa-gun, Ooyama-machi, Mozumi Pass	980	36 (2)	6	7	*NF990524*
24a.	Gifu Pref.: Yoshiki-gun, Kawai-mura, Kosaka Valley I	1060	36 (13)	13	13	*TS990602A*
24b.	Gifu Pref.: Yoshiki-gun, Kawai-mura, Kosaka Valley I	1060	24 (12)	12	12	*TS990602B*
25.	Gifu Pref.: Yoshiki-gun, Kawai-mura, Nara Pass B	1240	36 (24)	25	24	*TS980802, TS990602C*
26.	Toyama Pref.: Higashi-tonami-gun, Toga-mura, Higashimata	1320	36 (7)	15	20	*TS990909, TS990524B*
27.	Gifu Pref.: Yoshiki-gun, Kawai-mura, Amo Pass I	1300	36 (4)	7	17	*TS980801A, TS990606*
28.	Gifu Pref.: Oono-gun, Shirakawa-mura, Amo Pass II	1260	36 (3)	12	10	*TS990605*
29.	Gifu Pref.: Oono-gun, Shirakawa-mura, Ushikubi pass I	1000	36 (7)	15	16	*TS990526*
30.	Gifu Pref.: Oono-gun, Kiyomi-mura, Morimo Pass	1100	36 (4)	6	26	*TS980821, TS990512*
31.	Gifu Pref.: Yoshiki-gun, Miyakawa-mura, Kosaka Valley II	1060	36 (4)	6	10	*TS990602D*
32.	Gifu Pref.: Yoshiki-gun, Kawai-mura, Kosaka Valley III	1000	36 (2)	13	12	*TS990614*

TABLE 1. (continued)

Pop. no.	Locality	Altitude(m)	CHR(SCH)	SFM	SLM	Voucher specimen
33.	Gifu Pref.: Yoshiki-gun, Kawai-mura, Nara Pass A	1240	36 (12)	12	12	*TS980801B, TS990613*
34.	Toyama Pref.: Higashi-tonami-gun, Toga-mura, Atebyo Valley	1000	36 (3)	18	18	*TS00520, TS990524C*
35.	Gifu Pref.: Oono-gun, Shirakawa-mura, Ushikubi Pass II	1040	36 (5)	12	12	*TS00521, TS990724*
36.	Gifu Pref.: Yoshiki-gun, Kamitakara-mura, Oosaka Pass	940	24 (3)	7	11	*TS980422*
37.	Gifu Pref.: Gujyo-gun, Takasu-mura, Hirugano	860	24 (2)	10	15	*TS980414*
38.	Gifu Pref.: Oono-gun, Shokawa-mura, Makido	780	24 (1)	10	8	*TS980417*
39.	Gifu Pref.: Oono-gun, Shokawa-mura, Mitarai	840	24 (1)	11	14	*TS980415*
40.	Gifu Pref.: Takayama City, Harayama	660	24 (1)	9	8	*TS950325, TS980416*
41.	Gifu Pref.: Oono-gun, Shokawa-mura, Mumaya I	1040	24 (2)	5	15	*TS980418*
42.	Gifu Pref,: Oono-gun, Shokawa-mura, Mumaya II	1000	24 (2)	15	17	*TS980419, TS980626*
43.	Gifu Pref.: Oono-gun, Takane-mura, Hiwatakogen	1360	24 (5)	20	25	*TS000429, TS990930*
44.	Nagano Pref.: Kiso-gun, Kaida-mura, Nishino	1220	24 (2)	16	20	*TS940417A*
45.	Nagano Pref.: Kiso-gun, Kaida-mura, Ondahara,	1220	24 (2)	16	22	*TS940417B*
46.	Nagano Pref.: Kiso-gun, Kaida-mura, Nishimata	1200	24 (1)	16	18	*TS950409*
47.	Nagano Pref.: Kiso-gun, Kaida-mura, Higesawa	1160	24 (1)	12	25	*TS950408, TS99028*
48.	Nagano Pref.: Kiso-gun, Kiso-mura, Near Sakai Pass	1400	24 (4)	11	15	*TS950523, TS990929*
C4.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Kitamatairi	880	24 (3)			*TS990720*
C5.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Kurobishidaira	1640	24 (3)			*TS990701*
C6.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Wadano	800	24 (2)			*TS990404*
C7.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Minamimatairi	900	24 (5)			*TS990717*
C8.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Mt. Iwatake I	1170	24 (2)			*TS990926*
C9.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Mt. Iwatake II	1300	36 (12)			*TS990925*
C10.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Kotoriike	1120	36 (3)			*TS990718*
C11.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Ochikura	700	36 (2)			*MS990528*
C12.	Nagano Pref.: Kita-azumi-gun, Hakuba-mura, Kamishiro	800	36 (2)			*MS990525*
C13.	Nagano Pref.: Minami-azumi-gun, Azumi-mura, Konashidaira	1500	36 (2)			*TS980613*
C14.	Nagano Pref.: Minami-azumi-gun, Azumi-mura, Myojin	1550	36 (1)			*TS990708*
C15.	Toyama Pref.: Kami-niikawa-gun, Ooyama-machi, Oridate	1240	24 (2)			*TS980705*
C16.	Toyama Pref.: Kami-niikawa-gun, Ooyama-machi, Sukenobu I	1400	24 (4)			*NF000527A*
C17.	Toyama Pref.: Kami-niikawa-gun, Ooyama-machi, Sukenobu II	1400	24 (4)			*NF000527B*
C18.	Toyama Pref.: Kami-niikawa-gun, Ooyama-machi, Mt. Takahata	1240	36 (3)			*NF990524*
C19.	Gifu Pref.: Yoshiki-gun, Kamioka-cho, Ootawa Pass	1300	36 (5)			*TS980706*
C20.	Gifu Pref.: Yoshiki-gun, Miyakawa-mura, Gomisawa Valley	1050	36 (1)			*TS980821*

overall appearance, but they have usually been distinguished from each other by the shape of the calyx tube (Maekawa 1932, 1959, Ohwi 1975, 1984, Satake & Momiyama 1982), but plants indistinguishable by the shape of the calyx tube are occasionally found. Additionally, plants that can be discriminated from each other by leaf size and shape were sometimes found in the same locality and adjacent regions of the Chubu District during my field survey. Preliminary studies showed that triploid and diploid plants occur in natural populations of the species (Sugawara 1994). With that information as background, population samples were collected from various localities throughout the distribution area. The collections were examined to document the variability in morphological and karyological features of suspected taxonomic importance, and to determine whether chromosome number is related to morphological features, and to incorporate the results into a taxonomy of the species.

Materials and Methods

Plants of *Asarum fauriei* usually grow in broad-leaved deciduous forests dominated by *Fagus crenata* Blume and *Quercus mongolica* Fisch. var. *grosseserrata* (Blume) Rehder & E. H. Wilson and in wet place around deciduous forests. The plants bloom from March to May. Several varieties of *A. fauriei* have been named. *Asarum fauriei* var. *fauriei* was based on a specimen collected at Kamegaoka, Aomori Prefecture in the Tohoku District of northern Honshu, Japan (Franchet 1898), while var. *nakaianum* was based on specimens collected at Kamikochi, Nagano Pref., Chubu District, central Honshu, Japan, (Maekawa 1932). The populations examined in this study were selected from nearly the entire area of distribution of the species. Prior to analysis of morphological variation, cytological analysis was conducted on 69 populations (Table 1). Morphological variation was examined for 49 of these populations (Table 1). The number of individuals examined in each population is also shown in Table 1. Voucher specimens representative of each population were deposited in the Makino Herbarium (MAK), Tokyo Metropolitan University, Tokyo.

From the population samples the following characters were measured (Fig. 1): calyx tube length (a), calyx lobe length (b), stylar protuberance length (c), number of longitudinal ridges on the inner surface of the calyx tube (d), leaf blade length (e), leaf blade width (f), and number of trichomes per 5 mm square area on the upper surface of a leaf (g). These morphological features have been used as key characters in past taxonomic treatments (Maekawa 1932, 1959; Ohwi 1975, 1984, Satake & Momiyama 1982), or were newly discovered from my preliminary observations to have possible taxonomic value.

For floral parts, flowers collected from native habitats were fixed in FAA and were then measured with the aid of a binocular microscope.

Karyological investigations were made from plants transplanted into the botanical gardens of Tokyo Metropolitan University. The number of individuals examined in each locality is shown in Table 1. The methods for karyological investigations were described in a previous paper (Sugawara & Ogisu 1986).

Results

Flowers show a considerable variation in size of calyx tube and calyx lobe, stylar protuberance length, and number of longitudinal ridges on the inner surface of the calyx tube. Although attention has been paid to many morphological and cytological characters, particular attention was paid to several characters that have been regarded as being important in the taxonomy of *Asarum fauriei*. The results obtained from this study are described below under populations.

Occurrence of diploid and triploid plants and their geographical distribution

Somatic chromosome numbers, either $2n=24$ and $2n=36$, of each population are shown in Table 1. In the Japanese species of *Asarum* so far examined, the chromosome number $2n=24$ is the most common and has been regarded as being diploid (Ono 1960; Sugawara 1981). The two numbers reported here, $2n=24$ and $2n=36$, may be considered to diploid and triploid states. At most of the collection sites, the chromosome number was usually consistent among the plants at each site. Two different numbers, $2n=24$ and $2n=36$, were found in plants col-

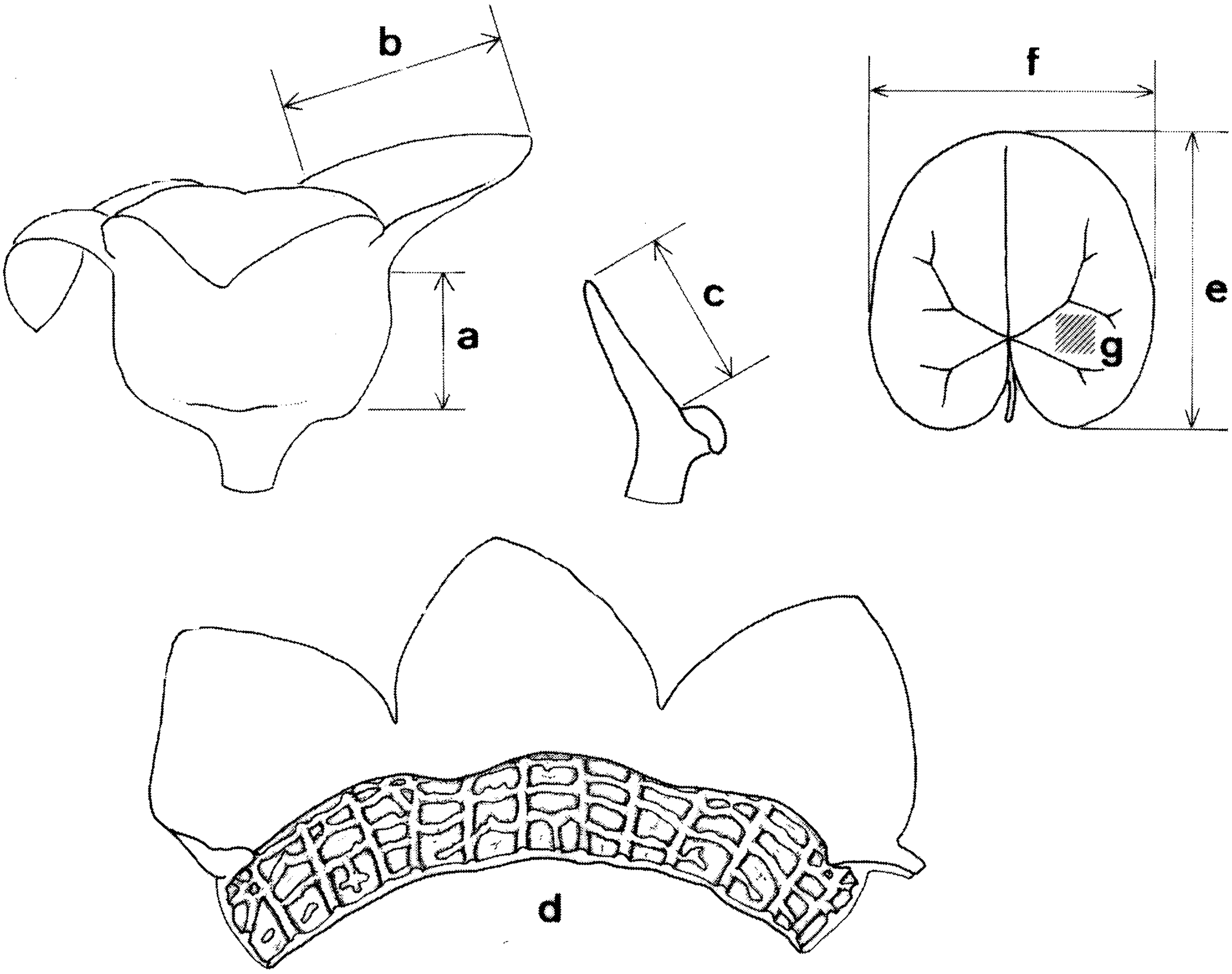

FIG. 1. Measurements of flowers and leaves. a, calyx tube length. b, calyx lobe length. c, stylar protuberance length. d, number of longitudinal ridges on inner surface of calyx tube. e, leaf blade length. f, leaf blade width. g, number of trichomes per 5 mm square on upper surface of leaf.

lected from the Kosaka Valley locality I. To further pursue examination of floral variation, the plants were tentatively divided into two groups (populations 24a and 24b) on the basis of chromosome number (Table 1).

In the diploid plants ($2n$=24) the two shortest chromosomes have centromere at the subterminal region (Fig. 2C). The other chromosomes have centromere in the median region. In the triploid plants ($2n$=36), the three shortest chromosomes, which have subterminal centromeres, were obvious; most of the other chromosomes were characterized by having median centromeres (Fig. 2A, B, and D). I could not find any significant differences between diploids and triploids in karyological aspect.

In their distribution, triploid plants were found widely in the study populations in central Honshu, while they were restricted to only a single population (population 7) in northern Honshu (Fig. 3).

Leaf blade length / leaf blade width

At Nara pass (populations 25 and 33), Kawai-mura, Yoshiki-gun, Gifu Pref., two groups of individuals that obviously differed from each other in leaf size and leaf shape were easily recognized despite having the same chromosome number $2n$ =36 (Fig. 4A). They also differ from each other in a few flo-

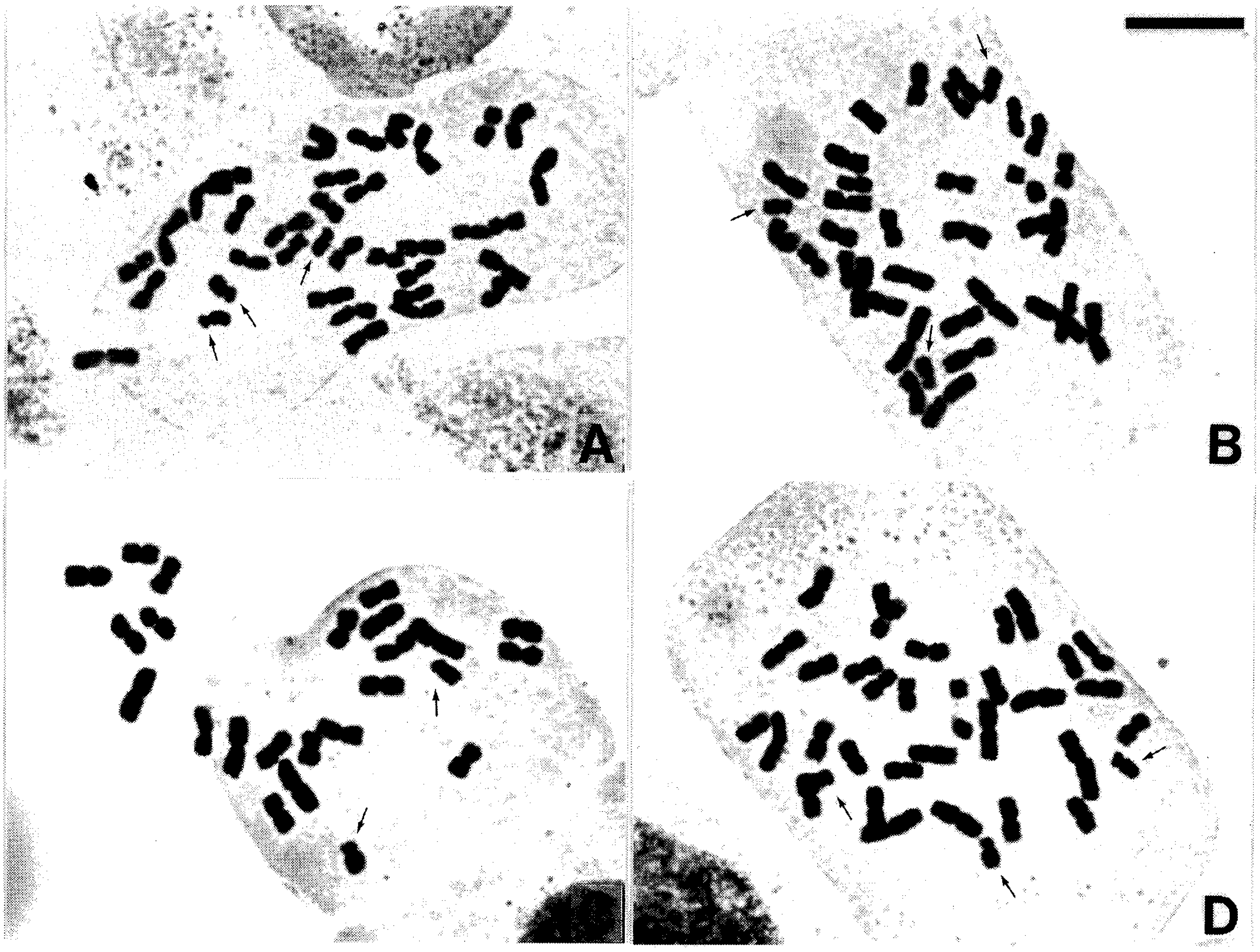

FIG. 2. Somatic metaphase chromosomes of *Asarum fauriei*. A, 2*n*=36 from Nakanoyu (population 14). B, 2*n*=36 from Morimo Pass (population 30). C, 2*n*=24 from Kosaka Valley I (population 24b). D, 2*n*=36 from Kosaka Valley I (population 24a). Scale bar represents 10μm. Arrows indicate small subterminal chromosomes.

ral characters, as described later in detail (see Fig. 4B). I therefore divided the plants at the locality into two populations, 25 and 33. The population 25 has smaller, orbicular leaves, while the population 33 has larger, ovate leaves.

The ratio of blade length to blade width was calculated to represent the leaf shape. The range, standard deviation and mean value of the ratio was examined in 49 population samples, as shown in Fig. 5A. It is evident that six populations of populations 30-35 differ from the other populations in having ovate leaves, but the variation is apparently continuous and no discrete gap was found among the populations when all collections are taken into account. It is also clear that there was no significant difference in leaf size and shape between the two populations 24a and 24b (see Fig. 7A), which differ from each other in chromosome number but occur side by side in the same locality.

Hairiness on the upper surface of a leaf blade

As shown in Fig. 5B, the number of trichomes between the nerves on the upper surface of the leaves varied considerably and no discrete gap was found among the populations. It was evident, however, that seven populations (populations 1 to 7) in northern Honshu and six populations (populations 19 to 23 and 24b) in central Honshu tended to be glabrous or sparsely hairy, while the other populations, especially in the northern Japanese Alps (pop-

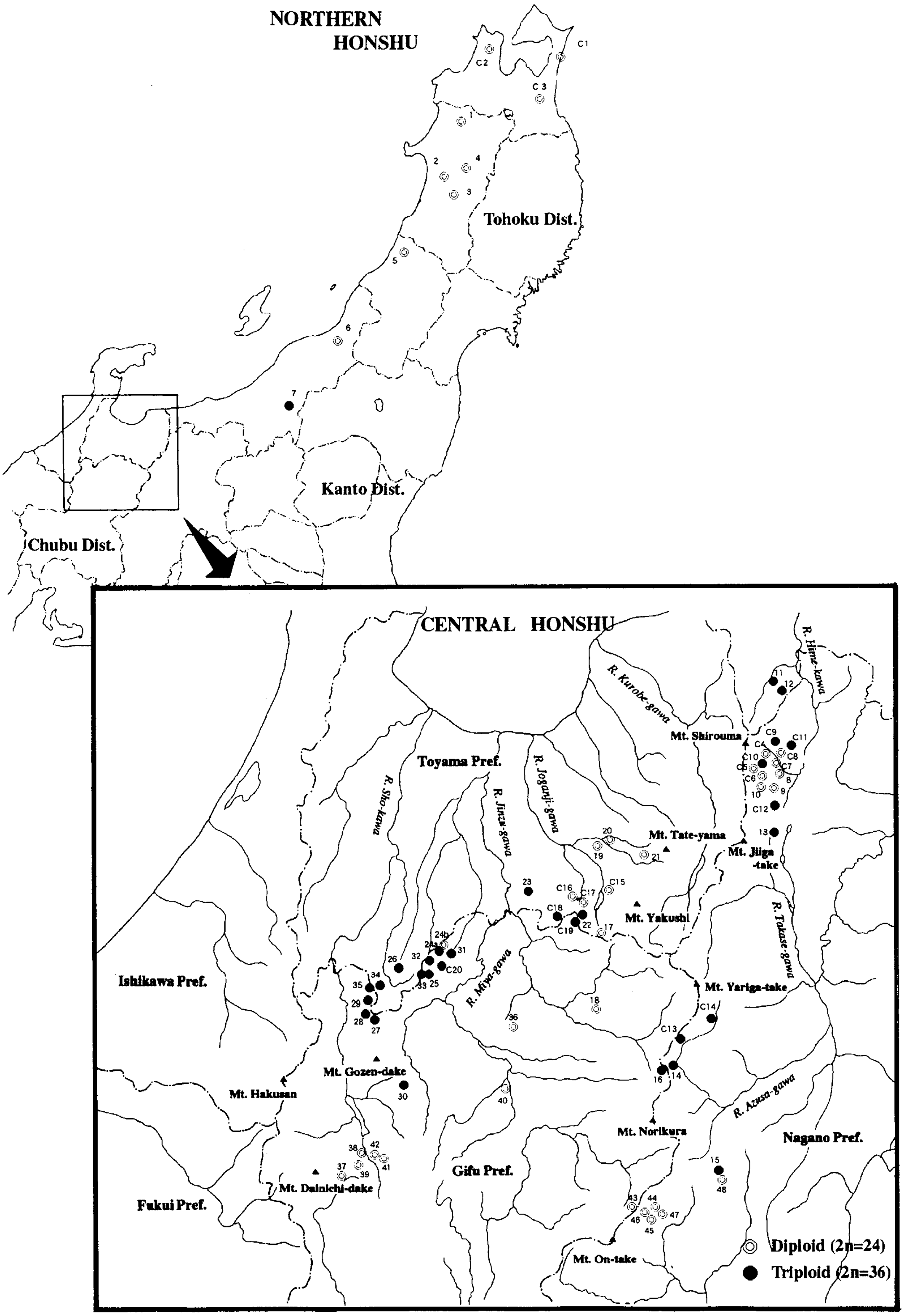

FIG. 3. Geographical distribution of diploid and triploid populations of *Asarum fauriei* in northern and central Honshu.

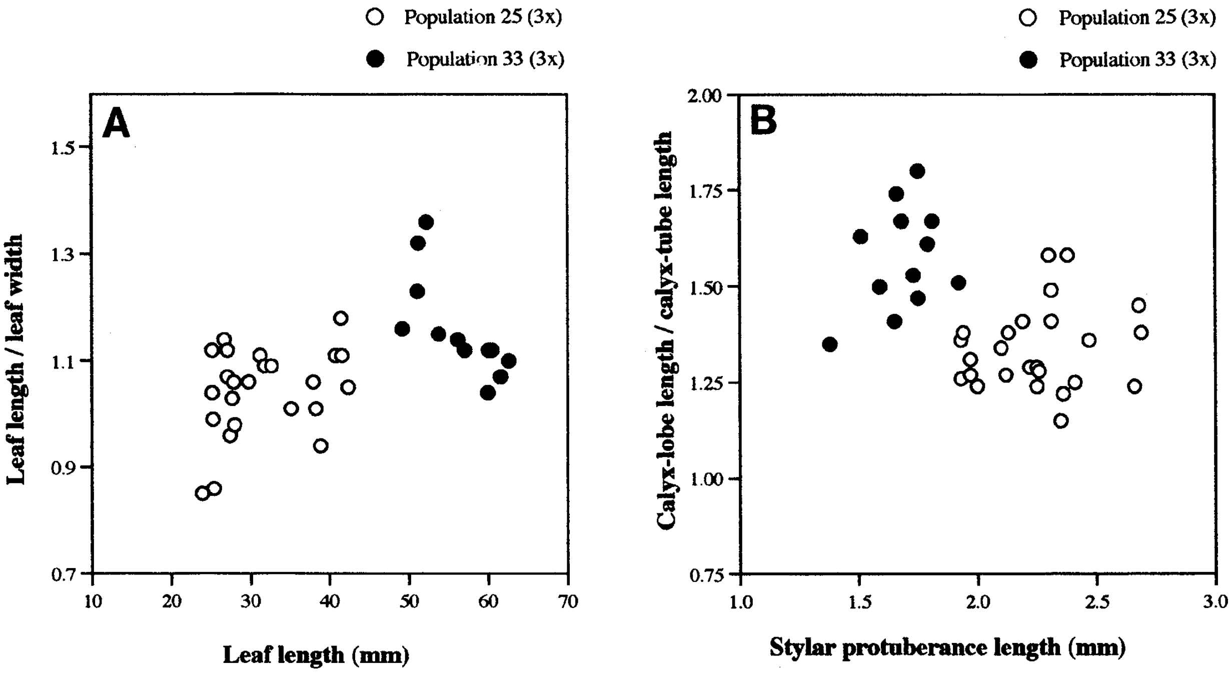

FIG. 4. Scatter diagrams showing relationship between leaf length and leaf length / leaf width (A), and between stylar protuberance length and calyx lobe length / calyx tube length (B) in plants from Nara Pass.

ulations 8 to 17), were densely hairy (Fig. 5B). It is noteworthy that populations 30-35, which have large and ovate leaves in common, are relatively sparsely hairy.

Calyx lobe length / calyx tube length

The plants studied here, especially those from the Chubu District, are characterized by having a shorter calyx tube compared with the calyx lobes (Maekawa 1932, 1959). The ratio of calyx lobe length to calyx tube length was calculated to represent the shape of the calyx tube. Range, standard deviation and mean value of this character from 49 population samples is shown in Fig. 6A. No discrete discontinuity was found among the populations, but six populations (populations 30 to 35) in northern Honshu and one population (population 6) in central Honshu tended to have higher values than the others.

Number of longitudinal ridges on inner surface of the calyx tube

The pattern of reticulation on the inner surface of the calyx tube has been a useful taxonomic character in *Asarum* (Sugawara 1998). To compare the pattern of reticulation, attention was paid to the number of longitudinal ridges extending from the base to the apex of the calyx tube. Range, standard deviation and mean value of the number of ridges in each population is shown in Fig. 6B. It can be seen from these figures that although the number of longitudinal ridges varied continuously among the populations, seven populations (populations 1-7) from northern Honshu and six populations (populations 30-35) from central Honshu tended to have nearly 12 longitudinal ridges. In contrast, the other populations usually had more than 12 longitudinal ridges.

Stylar protuberance length

Measurements of stylar protuberance length are shown in Fig. 6C. The stylar protuberance length varied considerably, and showed no discontinuity among the populations examined. However, stylar protuberance tended to be longer in five populations (populations 1-5) from northern Honshu and in two populations (populations 11and 13) from central Honshu. It is also noteworthy that the stylar protuberance length from population 6 located in north-

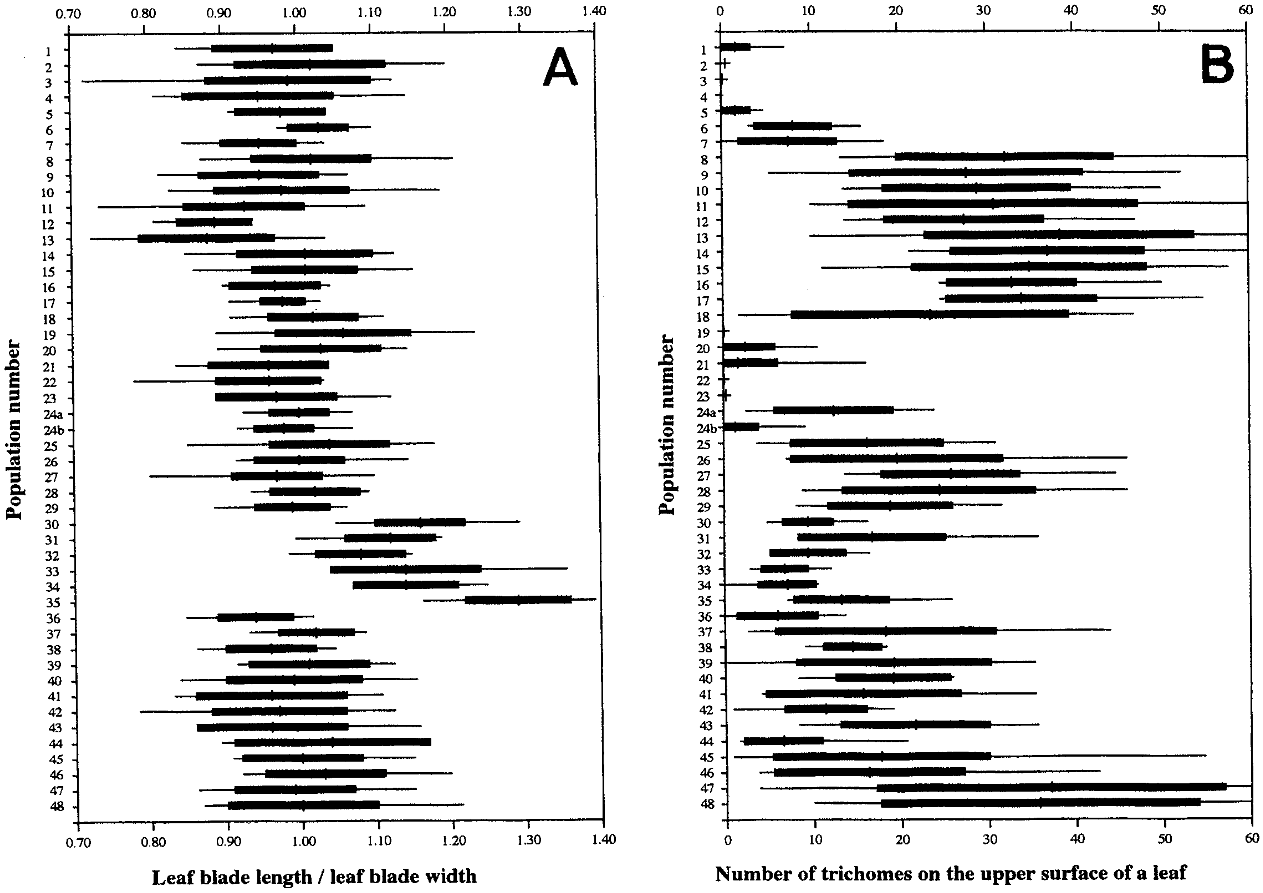

FIG. 5. Inter-populational variation of leaf blade length / leaf blade width ratio (A) and of number of trichomes on upper surface of leaf (B) in 49 populations of *Asarum fauriei*.

ern Honshu was conspicuously shorter.

As described above, two types of plants, which differ from each other in the size and leaf of the leaves, occurred side by side in the Nara pass locality. They were clearly separable from each other in floral morphology, as shown in the scatter diagram of stylar protuberance length and the ratio of calyx lobe length to calyx tube length (Fig. 4B). Two types of the plants (populations 24a and 24b), which differ from each other in chromosome number, were also found side by side in the Kosaka valley I. However, no discrete gap was found between them in several floral characters (Fig. 7B).

Principal component analysis (*PCA*)

To determine whether the populations concerned can be divided into groups when the five morphological characters described above are taken into account, the data obtained from 49 populations were subjected to principal component analysis. The first and second component axes clearly show that the populations are clustered into three major groups: the first group is composed of populations 1-5 and 7, the second group of populations 6 and 30 to 35, and the third group of the remaining populations (Fig. 8). The ratio of calyx lobe length to calyx tube length (+0.5195 in factor loading), the ratio of leaf length to leaf width (+0.4985) and the number of longitudinal ridges on the inner surface of the calyx tube (-0.5562) mainly contribute to the first component, and the stylar protuberance length (+0.7117) largely contributes to the second component (Table 2). The first two components explain 65.6% of the total variation. It can be seen from this figure that the first group is characterized by longer stylar protuberance, and that the second group is characterized

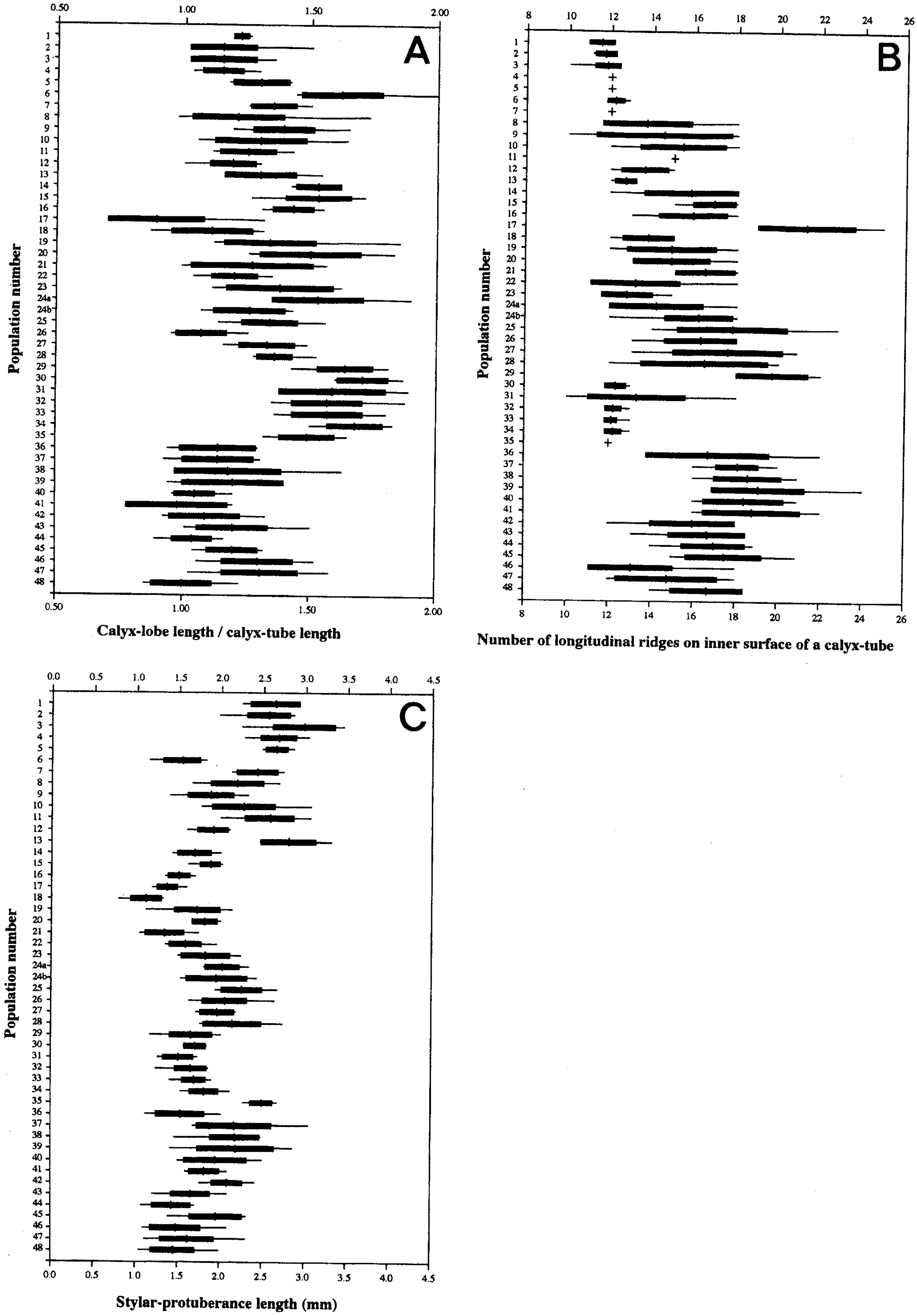

FIG. 6. Inter-populational variation of calyx lobe length / calyx tube length ratio (A), number of longitudinal ridges on inner surface of calyx tube (B) and stylar protuberance length (C) in 49 populations of *Asarum fauriei*. Dark box shows range between average plus-minus standard deviation. Ends of bars represent minimum and maximum values within a population.

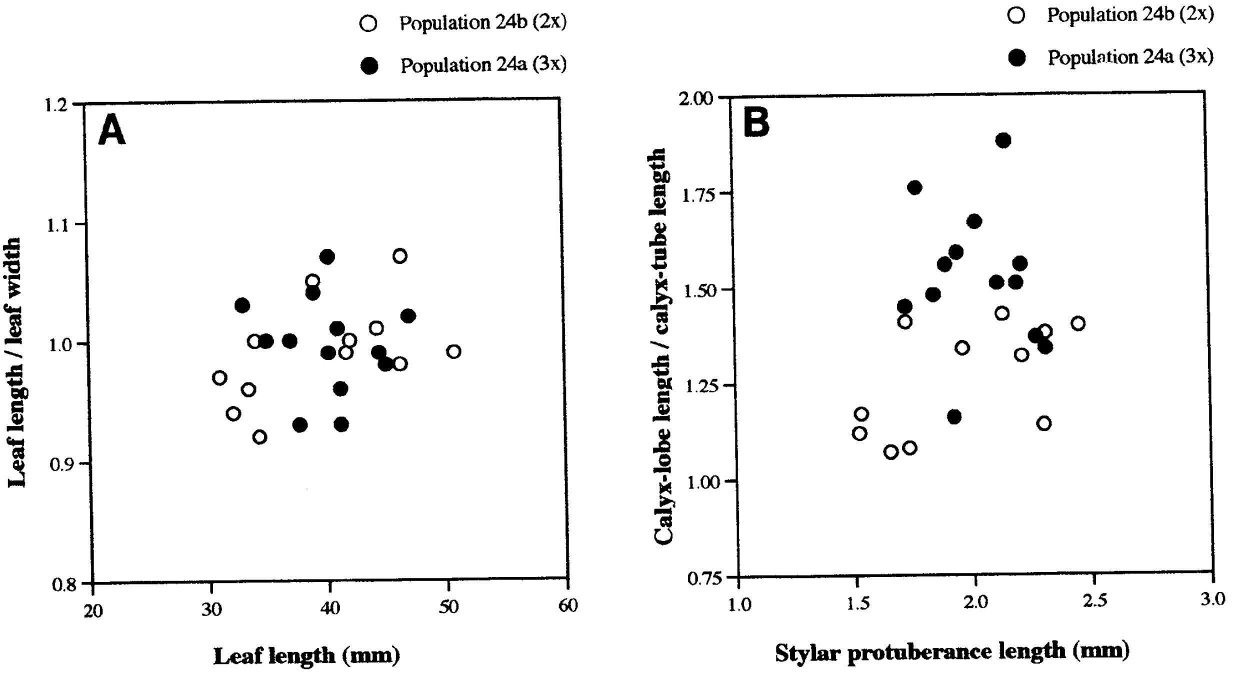

FIG. 7. Scatter diagrams showing relationship between leaf length and leaf length / leaf width (A), and between stylar protuberance length and calyx lobe length / calyx tube length (B) in individuals from Kosaka Valley I.

by ovate leaves and longer calyx lobes relative to the length of the calyx tube. In contrast, the third group is characterized by having more ridges on the inner surface of the calyx tube. The number of trichomes on the upper surface of the leaves (+0.7846) largely contributes to the third component. The third component explains 16.1% of the variation, and is not useful for clarifying the relationship among the populations.

Discussion

Relationship between diploids and triploids and origin of triploids

The results of this study clearly indicated that *Asarum fauriei* shows considerable variation in floral and leaf morphology, with occurrence of diploids ($2n$=24) and triploids ($2n$=36) between and even within study sites, and variation in floral and leaf morphology was unrelated to ploidy level.

In earlier studies (Tanaka 1935, Sugawara 1994) the occurrence of triploid plants of *Asarum fauriei* were reported for a few localities. It was confirmed from this study that the triploid plants occur widely, especially in the Chubu District of central Honshu. It is first necessary to discuss the interrelationships between the diploids and triploids and the origin of triploids in *A. fauriei*. The chromosome number of the plants examined was usually consistent within a study site. In Kosaka Valley-I (populations 24a and 24b), however, diploid and triploid plants grew side by side and they closely resembled each other in floral and leaf morphology. In Nara Pass (populations 25 and 33), two kinds of plants, which were all triploids and grew side by side, were clearly distinguished from each other in leaf shape and floral morphology. In considering these facts, two different triploid plants occurring in the same locality appear to have no direct relationship and may have arisen independently.

In general, the origin of triploids has been explained by two means: one is the result of hybridization between a tetraploid and a diploid, and the other is fertilization between unreduced ($2n$) and reduced (n) gametes (Stebbins 1971, Grant 1981, Tateoka 1983, see also Takano & Okada

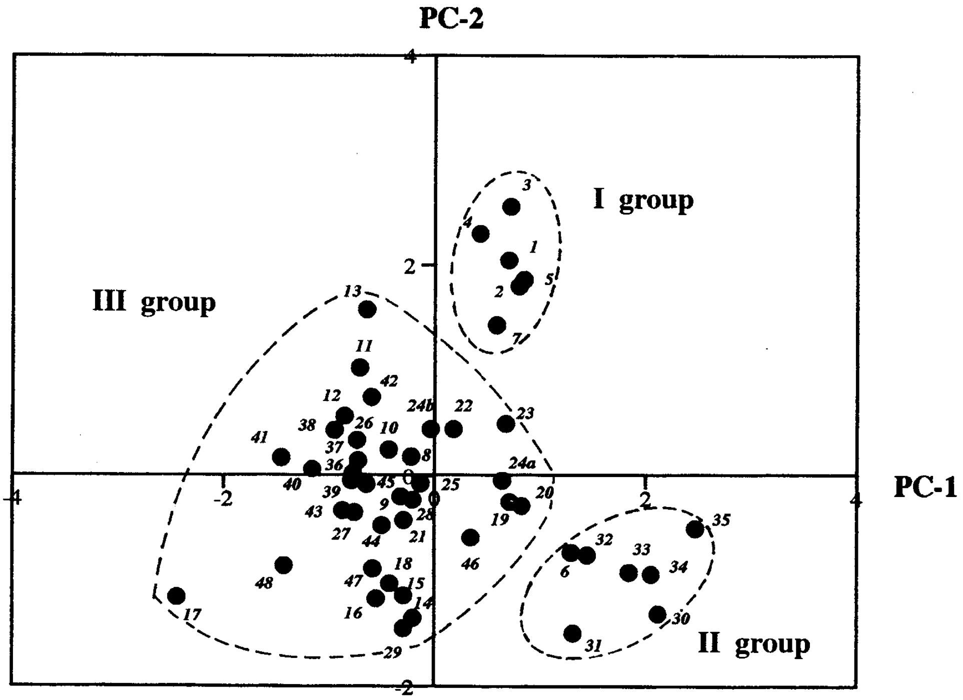

FIG. 8. Scatter diagram showing principal components 1 and 2 for 49 populations of *Asarum fauriei*. (see Table 2). Numbers inserted correspond to populations appearing in Table 1.

TABLE 2. Factor loading, eigenvalue, contribution, and accumulated contribution for principal components.

Character	Components		
	PC1	PC2	PC3
Leaf length / leaf width	0.4985	- 0.3937	-0.0703
Calyx-lobe length / calyx-tube length	0.5195	- 0.3619	0.3830
Number of longitudinal ridges on inner surface of a calyx tube	- 0.5562	- 0.3085	-0.1809
Stylar protuberance length	0.1103	0.7117	0.4471
Number of trichomes on adaxial surface of a leaf	- 0.4001	- 0.3353	0.7846
Eigenvalue	1.95	1.33	0.81
Contribution (%)	39.0	26.6	16.1
Accumulated contribution (%)	39.0	65.5	81.7

2002). Which mode might have resulted in the triploids in *Asarum fauriei*? As stated above, diploid and triploid plants are widespread and rarely occur together in the same area, but no tetraploid ($2n$=48) plants have been found so far within the geographic range of *A. fauriei*. The only known tetraploid species of *Asarum* is in *A. megacalyx*, which is morphologically dissimilar and geographically disjunct from *A. fauriei* (Sugawara 1998). The triploids found with the diploids, may have been derived sporadically from diploids by triploidization, such as from fertilization between an unreduced gamete ($2n$) and a reduced gamete (n), but might have not been the result of hybridization between diploids and tetraploids. To clarify the origin of triploids in *A. fauriei*, further cytological and genetic studies are needed.

Taxonomic considerations

All of the floral and leaf characters examined here varied continuously and no discrete gap was found among the populations of *Asarum fauriei*. However, as the five characters described above were subjected to principle component analysis, the 49 populations were clustered into three major groups. Representative flowers from three groups are shown in Fig. 9. Each of the three groups usually has a definite geographical range, with the exception of population 6, which is disjunct from the main range. The first population group occurs in northern Honshu and is characterized by having longer stylar protuberance. Additionally, it is mostly diploid, and rarely triploid (as in Hidarisawa population, population 7). The third population group occurs in the Japanese Alps in central Honshu and shows a wide range of variation in floral morphology. This group is characterized by having more numerous ridge reticulation on the inner surface of the calyx tube. The group includes two different chromosome numbers, diploids and triploids, which occur widely within the distribution area, but are mostly consistent within a population. Different ploidy levels rarely grow together within a population. The second population group is mostly triploid and is characterized by having longer calyx lobes and ovate leaves. Based on these finding, it seems best to recognize three different infraspecific taxa within *A. fauriei*, even though individual specimens may not always identifiable to one of the three taxa.

Among the three groups, the first and third groups, on the basis of morphology and geography, correspond to *Asarum fauriei* var. *fauriei* and var. *nakaianum*, respectively (Maekawa 1932, Ohwi

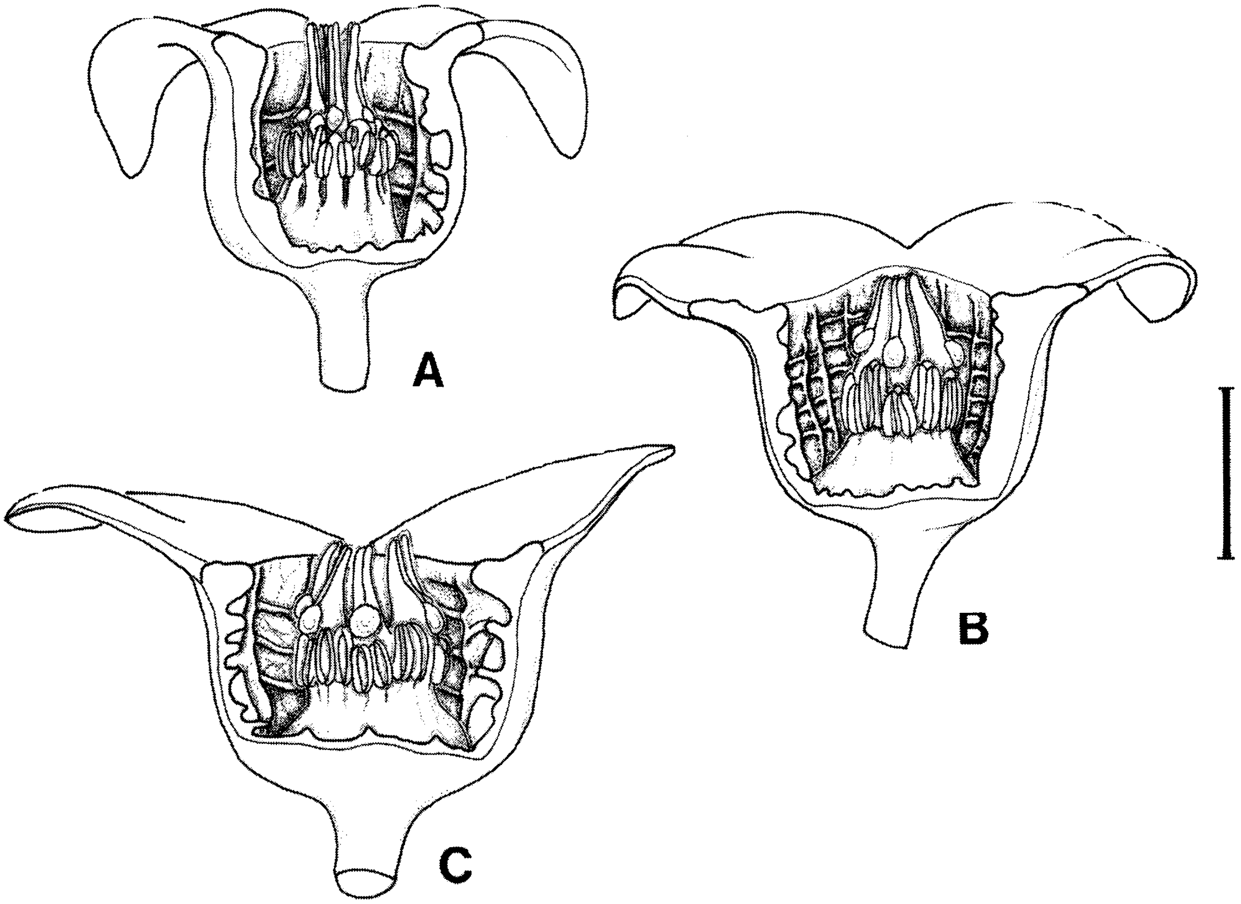

FIG. 9. Three representative flowers of *Asarum fauriei*. A, from Shirasawa (population 1). B, from Nakanoyu (population 14). C, from Atebyo Valley (population 34). Scale bar represents 5 mm.

1975, 1984). The second group may represent an undescribed taxon, but in the shape of the calyx tube and leaves it partly resembles *A. takaoi* F. Maek. of the lowlands in adjacent areas. To determine its taxonomic disposition, further comparative studies will be needed.

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